NAL PROPOSAL No. 0089

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INTERACTIONS OF 150 GeV π^- MESONS IN A LARGE NAL BUBBLE CHAMBER FILLED WITH H_2-Ne

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PROPOSAL TO NATIONAL ACCELERATOR LABORATORY

I. Cover Page

Title: Interactions of 150 GeV π^- Mesons in a Large NAL Bubble Chamber Filled with H_2-Ne

Abstract: We propose to study interactions of the highest energy negative pions available at NAL in the 14-foot chamber (or the largest available chamber) filled with a mixture of H_2 and neon. We will determine cross sections for diffractive production of three-pion, five-pion, and possibly seven-pion systems by negative pions on neon nuclei. We will also study events where neutral pions are produced, both coherently and in interactions with protons in the liquid, and will use the γ-veto capabilities of the chamber to reduce the background in 4c fits on protons such as $\pi^-p \rightarrow \pi^+\pi^-\pi^-p$. We will search for quarks among the beam particles and for these and other exotic states produced in the nuclear cascades.

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II. Physics Justification

We propose to do a simple exploratory experiment, as soon as possible after NAL start-up, exposing the largest available bubble chamber to the highest energy negative beam available. As a complement to already proposed HBC experiments, we propose for this experiment that the chamber be filled with a light Ne-H_2 mixture ($\sim$ 15% Ne for the 14-foot HBC). The Neon will permit study of:

1) <u>Multipion final states coherently produced on neon nuclei</u>

Verify whether 3π coherent production cross section is roughly independent of beam momentum as expected, or rising as Serpukhov results suggest;[1] look for higher $\pi^-\rho^o$, π^-f^o etc. states beyond the A_1, particularly verify the hint of $A_3(2^-)$ production observed[2] at 16 GeV. Systematic exploration of unnatural parity $J^P = 1^+, 2^-, 3^+$ etc., $I^G = 1^-$ meson spectrum. Verify 5π coherent production cross section rising with beam momentum (16 vs. 60 GeV)[1,3] and the peak in S(1930) region. Systematic study of unnatural parity spectrum decaying via ρA, fA, $\rho\rho\pi$, etc. Look for 7π and higher multiplicity coherent signals. With respect to possible competing spark chamber-counter experiments, this experiment is more general, should be possible to perform more quickly and simply (given the BC!) and should be less subject to complications due to background of reactions producing π^o's, especially π^o's and strange particles together in the forward direction (e.g. $\pi^-K^+K^-\pi^o$, $\pi^-\pi^\pm K^\pm K^o{}_2\pi^o$). We should be sensitive to at least some coherent reactions involving strange particles if a 4m or so BC is available. (The decay free path for K_1^0 is about 3 1/2m at 50 GeV).

Coherent interactions of mesons on nuclei have been a fruitful source of interesting new physics in recent years. Although most of the work has been done in heavy liquid bubble chambers, either propane-freon or H_2-Ne, the first work showing coherent interactions of high energy particles on nuclei was done in nuclear emulsions.(4) It is fitting to note that nuclear emulsions were used recently at Serpukhov to measure cross sections for these processes at the higher energies now available in that laboratory. The extension of this work to the highest energy particles soon to be available at NAL, and the use of the more precise instrument, a large H_2-Ne bubble chamber will be of very great interest.

Since the cross sections for diffractively produced objects are presumably more or less constant with energy, we can predict fairly well the yield of these enhancements in this experiment, and interesting results on diffraction processes with a moderate number of photographs can practically be guaranteed.

2) <u>Use of γ detection as veto to enrich sample of 4c fits</u>

At these energies the precision of momentum and fitting(5) makes it highly desirable to have π^0 detection capability, even for 4c fits. The neon will permit detection of most π^0's (and some K_2^0's and neutrons via secondary interactions) produced in hydrogen (and nuclear) reactions enabling us to measure 4, 6, 8, etc. prong 4c fit candidates nearly free of unseen neutral particles, often with the proton identified by stopping or energy loss in the relatively heavy liquid. Most complications of γ scanning are avoided if one need only establish that no γ (rather than exactly how many) is associated with a given event. Particularly for the high multiplicity events, the probability of the neon interactions not revealing themselves via extra protons or poor 4c fits in a large chamber should be large enough (more precise studies on this point are being carried out) that this technique should compete favorable with a large HBC for 4c fits. It will permit, in any case, study of 4c fit channels with bias and background problems different from these encountered by HBC and counter-spark chamber experiments.

3) Study of events with backward π^0's but no π^0 forward in the π^-p CMS

The major complications in doing physics with γ rays at $\sim$ 150 GeV will come from sorting out the γ's in the forward cone of the fit. At scanning, we can select events where there happen to be none of these γ's, and for these events we will measure the other γ's with precision comparable to present day < 30 GeV experiments, and higher detection efficiency. Thus $\pi^- + (p\pi^0, p2\pi^0$ etc.) $2\pi^-\pi^+ + (p\pi^0, p2\pi^0$, etc.) will be clean $\geq$ 4c fit channels not easily available by other techniques. In addition we should learn something about $\pi^+\pi^-$ + ($p\pi^-\pi^0$, $p\pi^-2\pi^0$, etc.) $2\pi^+2\pi^-$ + ($p\pi^-\pi^0$, $p\pi^-2\pi^0$, etc.). Study of these channels, and those below, will complement study of 4c-no-π^0 channels in a systematic classification of 150 GeV interactions, study of exchange mechanisms, higher mass state branching ratios, etc.

4) <u>Study of events with one forward π^0, (2 forward π^0)</u>

For those events where there is no evidence for more than 2 γ ray showers in the forward direction and where a proton track is identified, the resulting $\geq$ 5c fit (or $\geq$ 3c, if the two γ momenta are considered unmeasured) should permit a fairly clean sample of events not easily obtainable by other techniques. We could study, for example, $\pi^-\pi^0$ + ($p, p\pi^0$, $p\pi^+\pi^-$, $p\pi^0\pi^0$, $p\pi^+\pi^-\pi^0$, etc.); corresponding fits with $2\pi^-\pi^+\pi^0$, $3\pi^-2\pi^+\pi^0$ in the forward direction (ρ^-N^{*+}, $\pi^-\omega^0N^{*+}$, multiperipheral events, etc.); corresponding upper vertex charge exchange π^0 + ($p\pi^-$, $p\pi^-\pi^0$, etc.), $\pi^+\pi^-\pi^0$ + (ditto), etc.

For some configurations, and not too low $\pi^0\pi^0$ mass, we expect also to be able to study events with 2 forward π^0's, $\geq$ 2c even ignoring the γ momenta: $\pi^-2\pi^0$ + (p, $p\pi^0$, $p\pi^+\pi^-$, etc.), ($2\pi^-\pi^+2\pi^0$) + (ditto), ($2\pi^0$ or $2\pi^0\pi^+\pi^-$ etc.) + ($p\pi^-$, $p\pi^-\pi^0$ etc.).

We expect that coherent reactions with one π^0("ω^0" exchange) will be even less copious at 150 GeV than at 16 GeV relative to ordinary ("pomeron" exchange) diffraction production. We would be sensitive, however, to final states such as $2\pi^-\pi^+\pi^0$ if for some reason the $\Delta G = 0$ approximate selection rule becomes worse, rather than better as the beam momentum increases.

5) Long shots

The combination of bubble chamber generality and neon targets may increase our chances of finding some fundamentally new type of process or particle at these high energies (which after all is the main reason to be doing an early exploratory experiment!).

a) New types of particles created in very high energy density jets in nuclei.[6]

The possibility of several nucleons successively involved in a nuclear cascade, and the time dilation of the highly relativistic systems crossing the nucleus suggest that the effective target in the nucleus will usually be several times heavier than a nucleon (correspondingly increasing the CMS energy available over that in $\pi^- p$ collisions at the same beam momentum. Thus very heavy states and states of fundamentally new types could be created. Note also that successive interactions could build up step by step some highly strange object (or one with large quantum numbers of some sort highly charged, highly magnetized, highly spinning, highly strange, very high representation of $SU_{3 or 6}$, etc.). Some of these may not live long enough to be easily detected in accelerator secondary beams, but even if very short lived could reveal themselves to an exploratory scan and analysis by physicist. (Extra dense straight tracks blowing up, extra curved dark tracks, quark tracks, bumps in multiparticle mass spectra, etc.). Some of them may prefer to decay via π^o's, electromagnetically or leptonically and thus be more easily detected in a HLBC with direct γ and $e^\pm$ detection. The extra stopping and secondary interaction power of the relatively dense liquid may also give us advantages over pure hydrogen in our zoo research.

b) <u>Quarks</u>

BC experiments in high energy negative beams will be sensitive to long-lived quarks of charge -1/3 or -2/3 e coming from the accelerator. We would like, as a by product of this experiment, to try again at these higher energies to detect quarks by the techniques we tried at CERN in the early '60's.[7] We would like to install a veto warning light triggered by early beam tracks and recorded in some convenient way, e.g., similar to that used by Morrison et al.[8]

We will look for quarks also among secondary particles coming out of interactions in the chamber.

We know of no directly competing or similar experiments planned for NAL.

III. Experimental Arrangement

We would like to use the highest energy negative pions available at the time the experiment is to be done. We have used the figure 150 GeV/c as a nominal value of the momentum, but the exact value is not critical. It should, however, be substantially above 100 GeV/c in order to go considerably higher than the 60 GeV/c available at Serpukhov.

The NAL 14-foot chamber presumably will be in operation and available for use with H_2-Ne during the summer of 1973. The exact size of the chamber is not critical, but the larger the better for the γ and hydrogen interaction work. The exact percentage of neon will be specified later after we make some Monte Carlo calculations on γ-detection efficiencies, but we expect that the percentage of neon will be about 15% for the 14-foot chamber.

We request 250,000 pictures with an average of three or four beam tracks per picture. We estimate that under these conditions we will have about one hydrogen and two neon interactions per photograph. This would yield about 5000 3-prong coherent interactions and about 3000 5-prong coherent interactions. Per mb of 4-prong cross section it would yield some 10,000 hydrogen 4-prong interactions of which perhaps 10-15% would have no γ (4c fit), and another 30-50% would be fittable using the γ measured in the Neon-H_2.

Aside from beam-transport and bubble chamber, and timing counter for the quark search if we are early enough, no special equipment will be necessary for this experiment at NAL. The photographs will be scanned and pre-digitized (on $\geq$ 2 IPD's) at Berkeley, and will be measured on Spiral Reader or other automatic measuring devices at a location still to be determined. We will make a rapid scan for quarks, zoo, and 3, 5, and 7-prong events with no sign of nuclear break-up, followed by a more general scan with criteria to be determined after portions of the film have been examined.

The Orsay and University of Washington groups with which we are currently collaborating on high energy (5-16 GeV) π and K - BC experiments have expressed interest in joining us in this experiment. Both Orsay and University of Washington could commit another $\geq$ 2 IPD/lab. Both have or will have some form of automatic measurement capability by mid 1973.

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